CURRENT AND FREQUENCY CONTROL OF INDUCTION GENERATOR: SIMULATION USING MATLAB

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I declare that this thesis entitled "*Current and Frequency Control of Induction Generator: Simulation Using MATLAB"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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ABSTRACT

Induction machine is the most widely used machine nowadays in industry and generation systems. It haves two mains types that usually use, squirrel cage and wound type. This project is about the control of current and frequency of wound rotor induction generator in wind turbine generation system. By controlling the current and frequency at the rotor of the generator, the active and reactive power produce by the generator can be regulate and maximize the generator performance. To control the current and frequency of induction generator in wind turbine application, this project uses an AC/DC/AC converter that directly connected to rotor. AC/DC/AC converter is a bi-directional converter that enables the generator to operate above and below the synchronous speed thus allow the generator to generate and absorb power from the grid. This system is called Doubly Fed Induction Generator (DFIG) in wind turbine application system where the stator is directly connected to grid and the rotor is connected to grid via AC/DC/AC converter. This project use MATLAB software to simulate the system and analyze the result obtains from the simulation. From the result, it shows that this system is function successfully and the objective is achieved.

ABSTRAK

Mesin induksi adalah mesin yang paling meluas penggunaanya pada masa kini di industri dan sistem penjanaan. Mesin ini terbahagi kepada dua jenis iaitu jenis sangkar tupai dan rotor luka. Projek ini adalah tentang kawalan arus dan frekuensi penjana induksi dalam sistem penjanaan turbin angin. Dengan mengawal arus dan frekuensi di rotor penjana itu, kuasa aktiv dan reaktiv yang terhasil dari penjana boleh dilaraskan dan dapat memaksimumkan prestasi penjana itu. Untuk mengawal arus dan frekuensi penjana induksi dalam aplikasi turbin angin, projek ini menggunakan pengubah AC/DC/AC yang disambungkan terus pada rotor.Pengubah AC/DC/AC adalah pengubah dua arah yang membolehkan penjana untuk beroperasi di atas dan di bawah kelajuan penyegerakan dan seterusnya membenarkan penjana untuk menghasilkan dan menyerap tenaga dari grid. Sistem ini dipanggil Penjana Induksi Suapan Bergabung (PISB) dalam aplikasi turbin angin dimana stator disambung terus kepada grid dan rotor disambungkan ke grid melalui pengubah AC/DC/AC. Projek ini menggunakan perisian MATLAB untuk mensimulasi sistem yang dibina dan menganalisis hasil yang didapati dari simulasi. Dari hasil itu. Ia menunjukkan yang sistem ini berfungsi dengan berjayanya dan telah mencapai objektif.

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LIST OF SIMBOL

P	-	Active power
Q	-	Reactive power
A	-	Area of rotor
V	-	Wind velocity
D	-	Air density
P_R	-	Rotor power
P_{airgap}	-	Air gap power
s	-	Slip
P_G	-	Generator power
P_{WW}	-	Wind wheel turbine power
T_m	-	Mechanical torque
ω_r	-	Rotor speed
P_s	-	Stator power
T_{em}	-	Electromagnetic torque
ω_s	-	Stator speed
Idr	-	d-axis current
Iqr	-	q-axis current

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LIST OF ABBREVIATIONS

DFIG	Doubly Fed Induction Generator
PM	Permanet Magnet
DTC	Direct Torque Control
RSC	Rotor Side Converter
GSC	Grid Side Converter
PWM	Pulse Width Modulation
IGBT	Insulated Gate Bipolar Transistor
AC	Alternating Current
DC	Direct Current
PI	Proportional Integral
Crotor	Rotor Converter
Cgrid	Grid Converter
Tm	Mechanical Torque
PLL	Phase Locked Loop

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Induction machine is the most widely used machine nowadays in industry and generation system. It has two main types, squirrel –cage and wound rotor type for this project, wound rotor type will be use because of its advantages in wind turbine application. This paper describes wind generation models that use Doubly fed induction generator (DFIG) system for operation within power system in order to perform stability analysis and rotor control to maximize the power generated with the lowest impact on the grid voltage and frequency during normal operation and under several disturbances, such as a variable wind speed and transmission line earth fault. The discussed methods consider wind turbines based on induction generator and a grid-connected converter. The study is performed within the multiple technologies design tool MATLAB/Simulink.

1.1.1 Induction Generator

The technology of induction generator is based on the relatively mature electric motor technology. Induction motors are perhaps the most common types of electric motors used throughout the industry. Early developments in induction generators were made using fixed capacitors for excitation, since suitable active power devices were not available. This resulted in unstable power output since the excitation could not be adjusted as the load or speed deviated from the nominal values. This approach became possible only where a large power system with infinite bus was available, such as in a utility power system. In this case the excitation was provided from the infinite bus. [1]With the availability of high power switching devices, induction generator can be provided with adjustable excitation and operate in isolation in a stable manner with appropriate controls.Induction generator also has two electromagnetic components: the rotating magnetic field constructed using high conductivity, high strength bars located in a slotted iron core to form a squirrel cage; and the stationary armature similar to the one described in the previous paragraph for PM technology. Figure 1.1 shows the construction of a typical induction generator in a cross sectional view.

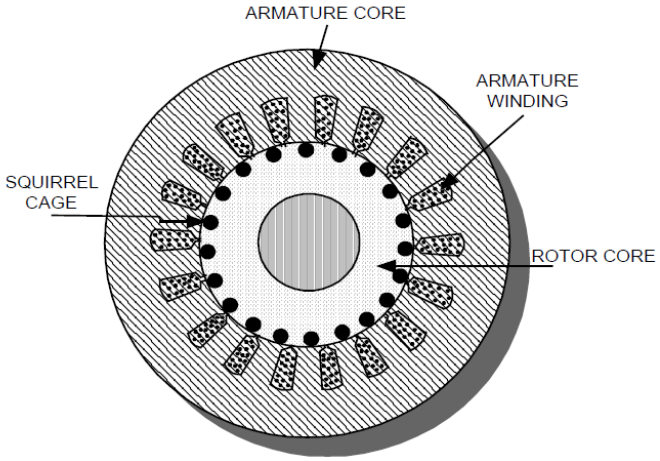

Figure 1.1 Induction Generator Cross- sectional view [1]

The voltage output from the generator is regulated, multiple phase AC. The control of the voltage is accomplished in a closed loop operation where the excitation

current is adjusted to generate constant output voltage regardless of the variations of speed and load current. The excitation current, its magnitude and frequency is determined by the control system. The excitation current is supplied to the stationary armature winding from which it is induced into the short circuited squirrel cage secondary winding in the rotor.

1.1.2 Doubly Fed Induction Generator (DFIG)

Doubly Fed Induction Generator is a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back-to-back voltage source converter that controls both the rotor and the grid currents. Thus rotor frequency can freely differ from the grid frequency (50 or 60 Hz). By controlling the rotor currents by the converter it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generators turning speed. The control principle used is either the two-axis current vector control or direct torque control (DTC). DTC has turned out to have better stability than current vector control especially when high reactive currents are required from the generator. Figure 1.2 shows the Principle of a Doubly Fed Induction Generator.

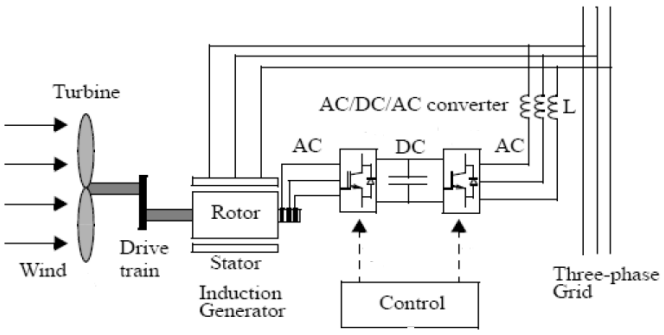

Figure 1.2 Principle of a Doubly Fed Induction Generator.[1]

The doubly-fed generator rotors are typically wound with from 2 to 3 times the number of turns of the stator. This means that the rotor voltages will be higher and currents respectively lower. Thus in the typical ± 30 % operational speed range around the synchronous speed the rated current of the converter is accordingly lower leading to a low cost of the converter. The drawback is that controlled operation outside the operational speed range is impossible because of the higher than rated rotor voltage

1.2 Problem Statement

This project are focused on the design and simulation of the Doubly Fed Induction Generator (DFIG) in order to control the current and frequency of induction generator using MATLAB/Simulink. DFIG contains a bi-directional or AC/DC/AC converter that function to control the induction generator output such as active power, reactive power, current and frequency. The general control structure of DFIG is shown in Figure 1.3 shows the basic control of DFIG where the converter are seperate in two part, rotor side converter (RSC) and grid side

converter (GSC) that controlled by pulse width modulation (PWM). The RSC is the converter that directly connected to rotor of the the induction generator while GSC is the converter that connect to the grid. This converter have diffirent function where the RSC function to control the current of the rotor while the GSC function to control the frequency of the generator. MATLAB/Simulink software is used to design and simulate this system.

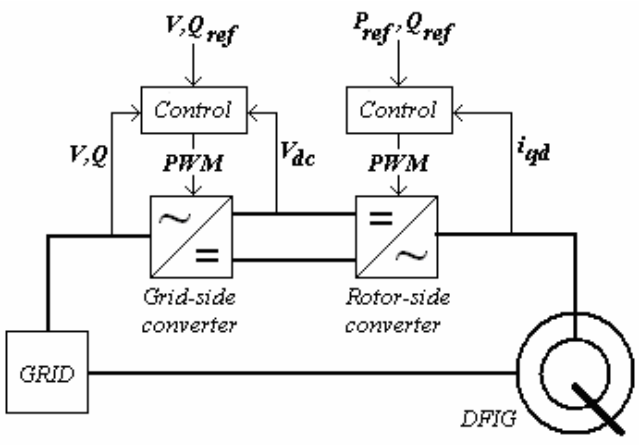

Figure 1.3 General Doubly Fed Induction Generator control structure[3]

1.3 Objective of Project

The objectives of this project are to:

1. Construct and simulate the current and frequency control of induction generator using Simulink in MATLAB

2. Design and simulate a wind generation model using doubly fed induction generator (DFIG) system using Simulink in MATLAB
3. Take the result obtains from the simulation and analyzes it to prove the theory

1.4 Scope of the Project

For this project, there two main scopes that must be completed in order to make sure this project will success:

1. Construct three phase AC/DC/AC converter in MATLAB that can control the current and frequency of the induction generator in Doubly Fed Induction Generator (DFIG) System.

2. Design and simulate a complete wind turbine generating system with focus on the generator side control using Doubly Fed Induction Generator (DFIG) system, where the stator side is directly connected to grid and the rotor side is connected to PWM converter. This system will also combine the entire controller and analyze the power flow and result of current and frequency of the generator to make sure the simulation have done as desired and success to control the current and frequency of the induction generator.

1.5 Thesis Outline

This thesis contains five chapters that clearly explaining about this project starting from introduction on Chapter 1, followed by literiture review on Chapter 2, methodology on Chapter 3, result and discussion on Chapter 4 and conclusion on Chapter 5

Chapter 1 is explaining about the background of study that explain about induction generator and DFIG. Secondly is the problem statement that clearly state about the fundamental of this project. After that, the objective of this project that show the objective or the reason of this project to be done followed by scope of the project and thesis outline.

Chapter 2 provides the information about literature review that explain about the paper that used as the references for this project. This chapter show the the present and previous method and technique used in control the induction generator.

Chapter 3 focuses on the method that have been used for this project including flowchart, methamatical modeling, metahmatical expression and electrical circuit. This chapter also discuss the basic about MATLAB and the method use in MATLAB to control the induction generator.

Chapter 4 discuss about the MATLAB block function as the result from method that use on Chapter 3 and analysis of the result obtain from the simulation using MATLAB.

Chapter 5 is about the conclusion, the problem encountered during this project and future recomendation for this project to improve this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Induction Generator operation

The operation of the induction motor occurs in a stable manner in the region of the speed torque curve indicated in Figure 2.1. The torque output as well as the power delivered by the motor varies as the motor speed changes.[3] At synchronous speed no power is delivered at all. The difference between the synchronous speed and the operating speed is called the slip. The output torque and power vary linearly with the slip.